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FORM PTO-1390 (REV 10-96) U S DEPARTMENT OF COMMERCE PATENT AND TRADEMARK OFFICE

ATTORNEY'S DOCKET NUMBER GDC-128

TRANSMITTAL LETTER TO THE UNITED STATES DESIGNATED/ELECTED OFFICE (DO/EO/US) CONCERNING A FILING UNDER 35 U.S.C. 371

U S APPLICATION NO (If known, see 37 CFR 1 5) 09/744324

INTERNATIONAL APPLICATION NO.	INTERNATIONAL FILING DATE	PRIORITY DATE CLAIMED
PCT/US99/16477	21 July 1999	22 July 1998

TITLE OF INVENTION Dynamic Buffer Management Scheme for ATM Switches

APPLICANT(S) FOR DO/EO/US HUSSAIN, Iftekhar and WORSTER, Thomas

Applicant herewith submits to the United States Designated/Elected Office (DO/EO/US) the following items and other information:

1. ☒ This is a **FIRST** submission of items concerning a filing under 35 U.S.C. 371.
2. ☐ This is a **SECOND** or **SUBSEQUENT** submission of items concerning a filing under 35 U.S.C. 371.
3. ☒ This express request to begin national examination procedures (35 U.S.C. 371(f)) at any time rather than delay examination until the expiration of the applicable time limit set in 35 U.S.C. 371(b) and PCT Articles 22 and 39(1).
4. ☒ A proper Demand for International Preliminary Examination was made by the 19th month from the earliest claimed priority date.
5. ☒ A copy of the International Application as filed (35 U.S.C. 371(c)(2))
   a. ☒ is transmitted herewith (required only if not transmitted by the International Bureau).
   b. ☐ has been transmitted by the International Bureau.
   c. ☐ is not required, as the application was filed in the United States Receiving Office (RO/US).
6. ☐ A translation of the International Application into English (35 U.S.C. 371(c)(2)).
7. ☐ Amendments to the claims of the International Application under PCT Article 19 (35 U.S.C. 371(c)(3))
   a. ☐ are transmitted herewith (required only if not transmitted by the International Bureau).
   b. ☐ have been transmitted by the International Bureau.
   c. ☐ have not been made; however, the time limit for making such amendments has NOT expired.
   d. ☐ have not been made and will not be made.
8. ☐ A translation of the amendments to the claims under PCT Article 19 (35 U.S.C. 371(c)(3)).
9. ☒ An oath or declaration of the inventor(s) (35 U.S.C. 371(c)(4)).
10. ☐ A translation of the annexes to the International Preliminary Examination Report under PCT Article 36 (35 U.S.C. 371(c)(5)).

Items 11. to 16. below concern document(s) or information included:

11 ☐ An Information Disclosure Statement under 37 CFR 1.97 and 1.98.

12 ☐ An assignment document for recording. A separate cover sheet in compliance with 37 CFR 3.28 and 3.31 is included.

13. ☐ A FIRST preliminary amendment.
 ☐ A SECOND or SUBSEQUENT preliminary amendment.

14. ☐ A substitute specification.

15 ☐ A change of power of attorney and/or address letter.

16 ☐ Other items or information:

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US APPLICATION NO. (if known, see 37 CFR 1.5)	INTERNATIONAL APPLICATION NO.	ATTORNEY'S DOCKET NUMBER
09/744324	PCT/US99/16477	GDC-128

17. ☒ The following fees are submitted:	CALCULATIONS	PTO USE ONLY
BASIC NATIONAL FEE (37 CFR 1.492 (a) (1) - (5)):		
Neither international preliminary examination fee (37 CFR 1.482) nor international search fee (37 CFR 1.445(a)(2)) paid to USPTO and International Search Report not prepared by the EPO or JPO $1000		
International preliminary examination fee (37 CFR 1.482) not paid to USPTO but International Search Report prepared by the EPO or JPO $860		
International preliminary examination fee (37 CFR 1.482) not paid to USPTO but international search fee (37 CFR 1.445(a)(2)) paid to USPTO $710		
International preliminary examination fee paid to USPTO (37 CFR 1.482) but all claims did not satisfy provisions of PCT Article 33(1)-(4) $690		
International preliminary examination fee paid to USPTO (37 CFR 1.482) and all claims satisfied provisions of PCT Article 33(1)-(4) $100		
ENTER APPROPRIATE BASIC FEE AMOUNT =	$ 100.00	
Surcharge of $130.00 for furnishing the oath or declaration later than ☐ 20 ☐ 30 months from the earliest claimed priority date (37 CFR 1.492(e)).	$	

CLAIMS	NUMBER FILED	NUMBER EXTRA	RATE		
Total claims	16 - 20 =	0	X $18.00	$	
Independent claims	3 - 3 =	0	X $80	$	
MULTIPLE DEPENDENT CLAIM(S) (if applicable)			+ $270	$	
TOTAL OF ABOVE CALCULATIONS =				$100.00	
Reduction of 1/2 for filing by small entity, if applicable. A Small Entity Statement must also by filed (Note 37 CFR 1.9, 1.27, 1.28).				$	
SUBTOTAL =				$100.00	
Processing fee of $130.00 for furnishing the English translation later than ☐ 20 ☐ 30 months from the earliest claimed priority date (37 CFR 1.492(f)). +				$	
TOTAL NATIONAL FEE =				$100.00	
Fee for recording the enclosed assignment (37 CFR 1.21(h)). The assignment must be accompanied by an appropriate cover sheet (37 CFR 3.28, 3.31). $40.00 per property +				$	
TOTAL FEES ENCLOSED =				$100.00	
				Amount to be: refunded	$
				charged	$

a. ☒ A check in the amount of $100.00 to cover the above fees is enclosed.

b. ☐ Please charge my Deposit Account No. ________ in the amount of $________ to cover the above fees. A duplicate copy of this sheet is enclosed.

c. ☒ The Commissioner is hereby authorized to charge any additional fees which may be required, or credit any overpayment to Deposit Account No. 07-1732. A duplicate copy of this sheet is enclosed.

NOTE: Where an appropriate time limit under 37 CFR 1.494 or 1.495 has not been met, a petition to revive (37 CFR 1.137(a) or (b)) must be filed and granted to restore the application to pending status.

SEND ALL CORRESPONDENCE TO:

David P. Gordon
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SIGNATURE:

David P. Gordon

NAME

29,996

REGISTRATION NUMBER

DYNAMIC BUFFER MANAGEMENT SCHEME FOR ATM SWITCHES

This application claims the benefit of provisional application Serial Number 60/093,681 filed July 22, 1998.

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates broadly to the field of telecommunications. More particularly, the present invention relates to the management of shared memory buffers in an asynchronous transfer mode (ATM) switch or node by setting of queue size and dynamic queue thresholds as functions of overall buffer occupancy and service category.

2. State of the Art

Perhaps the most awaited, and now fastest growing technology in the field of telecommunications in the 1990's is known as Asynchronous Transfer Mode (ATM) technology. ATM is providing a mechanism for removing performance limitations of local area networks (LANs) and wide area networks (WANs) and providing data transfers at a speed of on the order of gigabits/second. The variable length packets of LAN and WAN data are being replaced with ATM cells which are relatively short, fixed length packets. Because ATM cells can carry voice, video and data across a single backbone network, the ATM technology provides a unitary mechanism for high speed end-to-end telecommunications traffic.

Because the data contained in the ATM cells can be generated from either generally fixed rate communications, or bursty type communications, it will be appreciated that traffic accommodation mechanisms have been introduced in order to avoid situations where ATM switches or nodes are over-taxed, resulting in loss of cells. In particular, various buffering mechanisms are well known. Among these include input queues, output queues, and shared buffers. It is now generally agreed that

shared buffers are the preferred mechanism for implementing either input queues or output queues (or both) in an ATM switch.

The simplest implementation of shared memory buffers sets up queues for virtual connections (VCs) as needed and sets a queue length threshold for each queue regardless of the service category of the VC. This implementation is often referred to as the "Static Threshold" scheme. Arriving cells are admitted to the queue only if the queue length is smaller than the threshold set for the queue. Although the Static Threshold scheme is simple to implement, it does not adapt to changing traffic conditions. If one port in the switch (one VC) is very active, cells from that VC will be lost even if there is shared memory available to enlarge the queue.

Several "Dynamic Threshold" schemes have been proposed. These schemes attempt to adjust the queue length thresholds of all of the queues in shared memory based on the amount of currently available memory. One scheme for dynamic buffer management is disclosed in A. K. Choudhury and E. L. Hahne, Dynamic Queue Length Thresholds in a Shared Memory ATM Switch, Proc. IEEE INFOCOM '96 (San Francisco, California) pp. 1-9, March 1996 (hereinafter "Choudhury"). According to Choudhury, a control threshold $T(t)$ at time t is set (using notation of the present invention) equal to a multiple γ of the unused buffer space as shown in equation (1) where B is the total size of the shared buffer and U is the size of the used portion of the buffer.

$$T(t) = \gamma \cdot (B - U) \tag{1}$$

If any queue reaches a length greater than or equal to the control threshold $T(t)$, cells destined for that queue will be discarded. Choudhury states that γ should be a positive, negative, or zero power of two so that a shifter can be used to regulate the control threshold. According to Choudhury, γ is adjusted depending on whether the switch is moderately loaded or

heavily loaded and whether the load is uniform across all ports or non-uniform with one port more heavily loaded than others.

The Dynamic Threshold scheme of Choudhury is essentially a Static Threshold Scheme which is dynamically tuned according to load conditions in the switch. All VCs are treated equally and a certain amount of buffer space is intentionally wasted to accomplish this. The Choudhury scheme excels when there is a uniform load on the switch but does not provide much improvement over Static Threshold schemes when only a few ports in the switch are overloaded. Also, as specifically noted by Choudhury, the scheme does not address the issue of multiple service categories.

Current ATM service is offered in different categories according to a user's needs. Some of these categories include constant bit rate (CBR), variable bit rate (VBR), unspecified bit rate (UBR), and available bit rate (ABR). Some categories are given a higher priority than others when decisions are made to discard cells. For example, it is desirable that cells rarely, if ever, be discarded from CBR traffic. It has been recognized that the category of service should be taken into account when managing queues in shared memory. However, no scheme has been proposed for doing so.

SUMMARY OF THE INVENTION

It is therefore an object of the invention to provide a dynamic buffer management scheme for ATM switches.

It is also an object of the invention to provide a dynamic buffer management scheme which allocates shared buffer memory to VC queues based in part on the service category of the VC.

It is another object of the invention to provide a dynamic buffer management scheme which adjusts the allocation of shared

buffer memory to VC queues based in part on the service category of the VC and overall congestion in the ATM switch.

In accord with these objects which will be discussed in detail below, the buffer management scheme of the present invention sets different dynamic thresholds for different VCs according to the formula expressed in equation (2).

$$T_i(U) = T_{F_i} + \gamma_i \cdot (B - U) \tag{2}$$

As in equation (1), B is the total size of the shared buffer and U is the size of the used portion of the buffer. According to the invention, $T_i(U)$ is the threshold (in number of cells) for the i^{th} connection when the used portion of the buffer is U. T_{Fi} is the minimum required buffer threshold allocation (in number of cells) for the i^{th} connection buffer when the buffer is full and γ_i is preferably a power of two chosen for the i^{th} connection at the time the connection is set-up. Both T_{Fi} and γ_i are chosen based on the service category of the connection.

In addition, the buffer management scheme of the present invention sets minimum and maximum buffer sizes based on the service category of the connection. Preferably, a minimum buffer is guaranteed for service categories above UBR (unspecified bit rate). For UBR traffic, the minimum buffer available is determined by the number of backlogged connections. The maximum buffer size for each connection is a function of the total buffer size B, T_{Fi}, and γ_i.

Additional objects and advantages of the invention will become apparent to those skilled in the art upon reference to the detailed description taken in conjunction with the provided figures.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a graph of the relationship between dynamic threshold and overall buffer occupancy; and

Figure 2 is a flow chart illustrating the operations of an apparatus according to the invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

As mentioned above, a dynamic threshold $T(U)$ can be set such that if the number of cells Q_{VC} in a buffer equals or exceeds the threshold ($Q_{VC} \geq T(U)$), cells arriving at the buffer are discarded. Referring now to Figure 1, the dynamic threshold $T(U)$ is shown to be a linear function of the overall buffer occupancy U. In particular, it will be noted that as the overall buffer occupancy increases, the dynamic threshold decreases, i.e. cells will be discarded sooner. Thus, the linear function has a negative slope. The "y intercept" of the function, labelled "x" on the y-axis of Figure 1, is the integer value of the dynamic threshold when the overall buffer occupancy is empty. Thus, the minimum required buffer threshold allocation T_0 should be some integer number less than or equal to x. According to standard practices, buffer thresholds are set by add/subtract shift operations. Therefore, the slope of the function is preferably limited to an integer power of two, i.e. 2y. The intercept and the slope of the function $T(U)$ can be chosen so that the threshold has some value T_F when the buffer is full as shown in equation (3).

$$T(B) = T_F = x - 2^y B \tag{3}$$

Thus, the value of the intercept x can be expressed as shown in equation (4).

$$x = T_F + 2^y B \tag{4}$$

As mentioned above, the threshold when the buffer is empty should be less than or equal to x as shown in equation (5).

$$x \geq T_0 \tag{5}$$

Substituting equation (4) for x in equation (5) yields equation (6).

$$T_F + 2^y B \geq T_0 \tag{6}$$

Equation (6) can be rewritten as equation (7).

$$2^y \geq \frac{T_0 - T_F}{B} \tag{7}$$

Therefore, an appropriate algorithm for choosing the value of y in order to set the slope of the threshold function can be expressed as equation (8).

$$y = \left\lceil \log_2 \left(\frac{T_0 - T_F}{B} \right) \right\rceil \tag{8}$$

According to one embodiment of the invention, equations (4) and (8) may be used directly at the time a VC is set up to determine x and y from B, T_0, and T_F. However, in the preferred embodiment y is selected on a per class basis, i.e. the value of y depends solely on the service category and the size of the buffer. T_F is also preferably based solely on the service category.

With the above considerations in mind, the buffer threshold formula according to the invention can be expressed in simplified form as equation (9).

$$T_i(U) = T_{F_i} + \gamma_i (B - U) \tag{9}$$

As shown in equation (9), $T_i(U)$ is the threshold for the i^{th} connection buffer when the overall buffer usage is U. B is the total shared buffer size, and γ_i is 2^y where y is chosen for the

ith connection at the time the connection is set-up based on service category and total shared buffer size. The thresholds, buffer size and buffer usage are given as an integer number of cells.

According to a preferred embodiment of the invention, minimum and maximum queue occupancy levels (Q_{min} and Q_{max}) are also set by the dynamic thresholding scheme for each connection. Table 1 illustrates the presently preferred recommended dynamic threshold parameters for five different service categories.

Service Category	y	T_F	Q_{max}	Q_{min}
CBR	$\lceil \log_2(\frac{\alpha}{4B}) \rceil$	$\tau_{PCR} \cdot PCR$	$\frac{T_F + 2^y B}{(1+2^y)}$	$\tau_{PCR} \cdot PCR$
VBR-rt	$\lceil \log_2(\frac{\alpha}{4B}) \rceil$	$\tau_{PCR} \cdot PCR$	$\frac{T_F + 2^y B}{(1+2^y)}$	$\tau_{PCR} \cdot PCR$
VBR-nrt	-4	b_e	$\frac{T_F + 2^{-4} B}{(1+2^{-4})}$	b_e
ABR	-4	*TBE*	$\frac{T_F + 2^{-4} B}{(1+2^{-4})}$	*TBE*
UBR	0	0	$\frac{B}{2}$	$\frac{B}{(1+N)}$

Table 1

In Table 1, α is a dimensionless coefficient as defined by ITU I.371, the complete disclosure of which is hereby incorporated herein by reference. The default value of α is 120. PCR refers to the peak cell rate and τ_{PCR} refers to the cell delay variation tolerance or CDVT as defined in ITU I.371 for constant bit rate (CBR) and variable bit rate-real time (VBR-rt) service categories. As above, *B* is the size of the shared buffer in number of cells. b_e is the effective buffer size as defined in IEEE Journal on Selected Areas in Communications, Vol. 13, No. 6, pp. 1115-11127 (1995) and TBE is the transient buffer exposure as defined in ATM forum Traffic Management Specification 4.0, April 1996, #af-tm-0056.000. The minimum buffer size Q_{min} is the minimum size of the buffer in number of cells when the shared buffer is completely full. Q_{max} is the maximum queue occupancy (in number of cells) allowed for a particular connection. For unspecified bit rate (UBR) service, Q_{max} is purely a function of the total shared buffer size and Q_{min} is a function of total shared buffer size and number of backlogged connections N. For a given service category, the value of the y parameter should be chosen such that the resulting value of Q_{max} is greater than or equal to the maximum value of Q_{min} for the service category. Moreover, for a given service category, y should be set proportionally to the expected queue length of a connection in the category.

Several properties of the buffer management scheme can be ascertained from an analysis of the threshold formula shown in equation (9). For example, if there are N connections each having a queue threshold defined by T_{Fi} and γ_i, and if all connections are completely backlogged (i.e. their corresponding queue lengths are at their corresponding dynamic thresholds T_i ($i = 1, 2, 3, \ldots, N$)), then the steady-state vc threshold (or the queue length) for each connection i can be expressed as shown in equation (10).

(10) $$T_i = Q_{vc_i} = \frac{T_{F_i} \cdot \left(1 + \sum_{k=1(k \neq i)}^{N} \gamma_k\right) + \gamma_i \cdot \left(B - \sum_{k=1(k \neq i)}^{N} T_{F_k}\right)}{\left(1 + \sum_{k=1}^{N}\right)}$$

The truth of equation (10) can be proven by iterative computation for N≥2. For example, where N=2, there will be two iterations of equation (9), one for i=1 and one for i=2. If the second equation is rewritten as a function of U as shown in equation (11), it can be substituted into the first equation to establish the relationship between the two thresholds as shown in equation (12).

(11) $$U = \frac{(T_{F_2} - T_2)}{\gamma_2} + B$$

(12) $$T_1 = T_{F_1} - \frac{\gamma_1}{\gamma_2} \cdot T_{F_2} + \frac{\gamma_1}{\gamma_2} \cdot T_2$$

Under a complete backlog condition $U=T_1+T_2$ which can be used to rewrite the second iteration of equation (9), i.e. where $i=2$, as equation (13).

(13) $$T_2 = T_{F_2} + \gamma_2 B - \gamma_2 T_1 - \gamma_2 T_2$$

Substituting equation (12) in equation (13) yields equation (14) which is exemplary of equation (10).

(14) $$T_2 = \frac{T_{F_2} \cdot (1+\gamma_1) + \gamma_2 \cdot (B - T_{F_1})}{(1+\gamma_1+\gamma_2)}$$

Similarly, if the expression for T_2 from equation (14) is substituted in equation (12), equation (15) is produced which is also exemplary of equation (10).

(15) $$T_1 = \frac{T_{F_1} \cdot (1+\gamma_2) + \gamma_1 \cdot (B - T_{F_2})}{(1+\gamma_1+\gamma_2)}$$

Repeating this process iteratively for higher values of N, will establish the truth of equation (10).

A first corollary to the proof of equation (10) is that if there are N backlogged connections, each with the same γ_i but with different T_{Fi}, then their steady-state queue lengths will be given by equation (16).

(16) $$T_i = Q_{wc_i} = \frac{T_{F_i}(1+(N-1)\gamma) + \gamma\left(B - \sum_{k=1(k\neq i)}^{N} T_{F_k}\right)}{(1+N\gamma)}$$

A second corollary to the proof of equation (10) is that if there are N backlogged connections with the same γ_i and with the same T_{Fi}, then their steady-state queue lengths will be given by equation (17).

(17) $$T_i = Q_{wc_i} = \frac{T_F + \gamma B}{(1+N\gamma)}$$

The analytical results of equations (10), (16), and (17) were compared with simulation results obtained by simulating three connections sharing a common memory pool. The simulation

memory was partitioned into per connection logical queues. Complete backlogged conditions were created by having per connection input rates exceed the output rates. A comparison of the simulation results with the analytical results is illustrated in Table 2.

Number of Connections	Connection Parameters (B=1,000 cells)			Queue Lengths via Analytical Results			Queue Lengths via Simulations		
	γ_1, T_{F1}	γ_2, T_{F2}	γ_3, T_{F3}	Q_1 cells	Q_2 cells	Q_3 cells	Q_1 cells	Q_2 cells	Q_3 cells
1	1,10	-	-	505	-	-	504	-	-
2	1,10	2,15	-	253.7	502.5	-	254	502	-
3	1,10	2,15	4,20	129.3	253.7	497.5	128	254	498
3	1,10	1,20	1,30	245	255	265	244	256	264

Table 2

As can be seen in Table 2, the analytical results and the simulation results are virtually identical. The small differences between the results are because the simulation results were truncated to the nearest integer.

Those skilled in the art will appreciate that the dynamic buffer management scheme may be implemented in a combination of hardware and software in order to perform the functions outlined above. Referring now to Figure 2, an apparatus according to the invention will determine at 10 when a new virtual connection is about to be established. If a new VC is being established, the apparatus will determine at 12 the service category of the new VC and will set the parameters based on the service category at 14. These parameters include T_F, γ, Q_{max}, and Q_{min}. At 16, the apparatus will determine the amount of free space in the shared buffer and at 18 the apparatus will set the dynamic queue threshold using equation (9). The apparatus will return to step

10. When no new VC is being established the apparatus will continue to monitor the amount of free space in the shared buffer at 16 and will reset the dynamic queue thresholds at 18 accordingly. Based on the queue thresholds, determination may be made by the apparatus to discard cells which would cause the queue length to exceed the queue threshold.

There have been described and illustrated herein several embodiments of a dynamic buffer management scheme for ATM switched. While particular embodiments of the invention have been described, it is not intended that the invention be limited thereto, as it is intended that the invention be as broad in scope as the art will allow and that the specification be read likewise. It will therefore be appreciated by those skilled in the art that yet other modifications could be made to the provided invention without deviating from its spirit and scope as so claimed.

Claims:

1. A dynamic buffer management method for managing multiple ATM queues in a shared buffer, comprising:

a) creating a queue for each virtual connection at the time the virtual connection is set up;

b) setting a minimum queue threshold for each queue at the time it is created based on the service category of the virtual connection for which the queue was created;

c) dynamically adjusting the queue threshold for each queue based on the minimum queue threshold and the amount of unused shared buffer space.

2. A method according to claim 1, wherein:

said step of adjusting includes increasing the minimum queue threshold by a fractional amount of the unused shared buffer space.

3. A method according to claim 2, wherein:

the fractional amount which is added to the minimum queue threshold is determined by the service category of the virtual connection for which the queue was created.

4. A method according to claim 1, further comprising:

d) setting a maximum permitted queue occupancy for each queue at the time it is created based on the service category of the virtual connection for which the queue was created.

5. A method according to claim 4, wherein:

the maximum permitted queue occupancy is a fractional amount of the dynamically adjusted queue threshold when the buffer is empty.

6. A method according to claim 4, further comprising:

e) setting a minimum queue occupancy for each queue at the time it is created based on the service category of the virtual connection for which the queue was created.

7. A method according to claim 6, wherein:

the minimum queue occupancy is based on the number of active backlogged connections.

8. A dynamic buffer management method for managing multiple ATM queues in a shared buffer, comprising:

a) creating a queue for each virtual connection at the time the virtual connection is set up;

b) setting a minimum queue threshold T_{Fi} for each i^{th} queue at the time it is created based on the service category of the virtual connection for which the queue was created;

c) dynamically adjusting the queue threshold for each queue based on the formula

$$T_i(U) = T_{F_i} + \gamma_i \cdot (B - U)$$

where B is the total size of the shared buffer, U is the size of the currently used portion of the buffer, γ_i is a fraction based on the service category of the virtual connection for which the queue was created, and $T_i(U)$ is the dynamically adjusted threshold (in number of cells) for the i^{th} connection when the used portion of the buffer is U.

9. A method according to claim 8, wherein:

$\gamma_i = 2^y$ where y is chosen based on the service category of the connection.

10. A method according to claim 9, further comprising:

d) setting a maximum permitted queue occupancy Q_{max} for each queue at the time it is created based on the formula

$$Q_{max} = \frac{T_F + 2^y B}{(1 + 2^y)}$$

11. A method according to claim 10, wherein:

for CBR service and for VBR-rt service $y = \lceil \log_2 \frac{\alpha}{4B} \rceil$ and $T_F = \tau_{PCR} \cdot PCR$;

for VBR-nrt service y=-4 and $T_F=b_e$.

for ABR service y=-4 and $T_F=TBE$; and

for UBR service y=0 and $T_F=0$.

12. An apparatus for dynamically managing multiple ATM queues in a shared buffer, comprising:

a) means for creating a queue for each virtual connection at the time the virtual connection is set up;

b) means of setting a minimum queue threshold for each queue at the time it is created based on the service category of the virtual connection for which the queue was created;

c) means for dynamically adjusting the queue threshold for each queue based on the minimum queue threshold and the amount of unused shared buffer space.

13. An apparatus according to claim 12, wherein:

said means for dynamically adjusting includes means for increasing the minimum queue threshold by a fractional amount of the unused shared buffer space.

14. An apparatus according to claim 13, wherein:

said means for dynamically adjusting includes means for determining the fractional amount which is added to the minimum queue threshold based upon the service category of the virtual connection for which the queue was created.

15. An apparatus according to claim 12, further comprising:

d) means for setting a maximum permitted queue occupancy for each queue at the time it is created based on the service category of the virtual connection for which the queue was created.

16. An apparatus according to claim 15, further comprising:

e) means for setting a minimum queue occupancy for each queue at the time it is created based on the service category of the virtual connection for which the queue was created.

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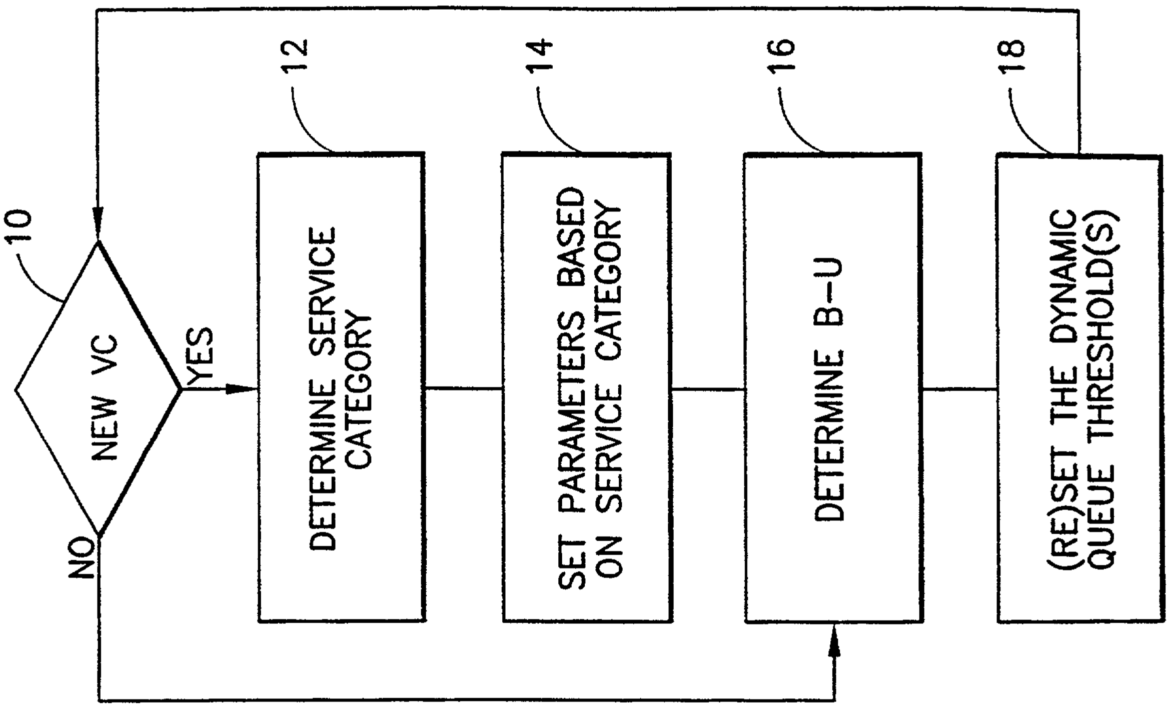

FIG.2

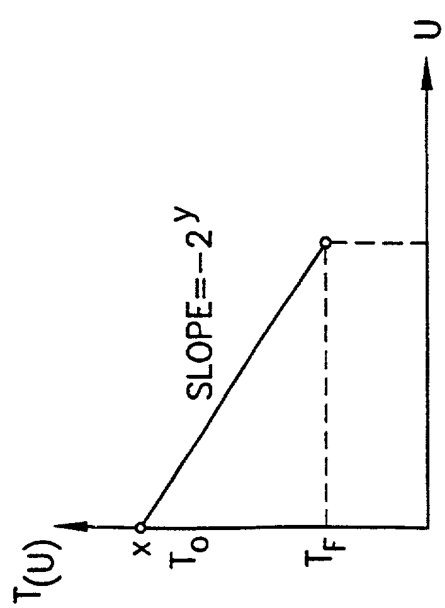

FIG.1

DECLARATION FOR PATENT APPLICATION AND POWER OF ATTORNEY

As below named inventor, I hereby declare that:

My residence, post office address and citizenship are as stated below next to my name, and

I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed for and for which a patent is sought on the invention entitled

DYNAMIC BUFFER MANAGEMENT SCHEME FOR ATM SWITCHES,

the specification of which

[ ] is attached hereto.

[X] was filed on: January 19, 2001

as application Serial Number: 09/744,324

and was amended on (if applicable):

I hereby state that I have reviewed and understand the contents of the above identified specification, including the claims, as amended by any amendment referred to above.

I acknowledge the duty to disclose information which is material to the examination of this application in accordance with Title 37, Code of Federal Regulations, Section 1.56(a).

I hereby claim foreign priority benefits under Title 35, United States Code, Section 119 of any foreign application(s) for patent or inventor's certificate listed below and have also identified below any foreign application for patent or inventor's certificate having a filing date before that of the application on which priority is claimed:

	Serial No.	Country	Filing Date (D/M/YR)	Prioity Claimed?	
1.	PCT/US99/16477	PCT/US	22/07/99	[X] YES	[ ] NO
2.				[ ] YES	[ ] NO

I hereby claim the benefit under Title 35, United States Code, Section 120 of any United States application(s) listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States application in the manner provided by the first paragraph of Title 35, United States Code, Section 112, I acknowledge the duty to disclose material information as defined in Title 37, Code of Federal Regulations, Section 1.56(a) which occurred between the filing date of the prior application and the national or PCT international filing date of this application:

Application Ser. No.	Filing Date	Status (patented, pending, abandoned)
1.		
2.		
3.		

As a named inventor, I hereby appoint the following attorney(s) and/or agent(s) to prosecute this application and transact all business in the Patent and Trademark Office connected therewith:

David P. Gordon (29,996)
David S. Jacobson (39,235)
Thomas A. Gallagher (31,358)

3

Address all telephone calls to: David P. Gordon at (203) 329-1160
Address all correspondence to: David P. Gordon, Esq.
65 Woods End Road
Stamford, Connecticut 06905
U.S.A.

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

SOLE OR FIRST INVENTOR

Signature: Iftekhar Hussain Date 01/22/2001

1∅ Full Name: Iftekhar Hussain

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SECOND INVENTOR

Signature: ______________________ Date ____________

Full Name: Thomas Worster

2∅ Residence: 199 W. Newton Street, Apartment 2, Bolton, MA 02116

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Citizenship: GB

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DECLARATION FOR PATENT APPLICATION AND POWER OF ATTORNEY

As below named inventor, I hereby declare that:

My residence, post office address and citizenship are as stated below next to my name, and

I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed for and for which a patent is sought on the invention entitled

DYNAMIC BUFFER MANAGEMENT SCHEME FOR ATM SWITCHES,

the specification of which

[ ] is attached hereto.

[X] was filed on: January 19, 2001

as application Serial Number: 09/744,324

and was amended on (if applicable):

I hereby state that I have reviewed and understand the contents of the above identified specification, including the claims, as amended by any amendment referred to above.

I acknowledge the duty to disclose information which is material to the examination of this application in accordance with Title 37, Code of Federal Regulations, Section 1.56(a).

I hereby claim foreign priority benefits under Title 35, United States Code, Section 119 of any foreign application(s) for patent or inventor's certificate listed below and have also identified below any foreign application for patent or inventor's certificate having a filing date before that of the application on which priority is claimed:

	Serial No.	Country	Filing Date (D/M/YR)	Prioity Claimed?	
1.	PCT/US99/16477	PCT/US	22/07/99	[X] YES	[ ] NO
2.				[ ] YES	[ ] NO

I hereby claim the benefit under Title 35, United States Code, Section 120 of any United States application(s) listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States application in the manner provided by the first paragraph of Title 35, United States Code, Section 112, I acknowledge the duty to disclose material information as defined in Title 37, Code of Federal Regulations, Section 1.56(a) which occurred between the filing date of the prior application and the national or PCT international filing date of this application:

Application Ser. No.	Filing Date	Status (patented, pending, abandoned)
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As a named inventor, I hereby appoint the following attorney(s) and/or agent(s) to prosecute this application and transact all business in the Patent and Trademark Office connected therewith:

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SOLE OR FIRST INVENTOR

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